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CHAPTER 4.

Conducting the Biosurvey

The primary goals of a bioassessment-biocriteria program are to evaluate water resource integrity, to provide information on the attainability and appropriateness of existing uses, and to determine the extent and degree of water resource impairment.

State bioassessment-biocriteria programs are usually designed to address one or more of four water resource management objectives:

1. **Aquatic Life Use Designation.** Determine and assess aquatic life uses that should be attained in streams and rivers. Helping to designate and assess aquatic life uses is a major function of biological criteria.

2. **Sensitive Waters Identification.** Characterize high quality waters for protection. High quality waters may become part of the reference database or be classified separately as unique waters.

3. **Diagnostics.** Determine sources of impairment and potential stressors. Biological response signatures are used in conjunction with chemical, toxicological, and physical data to identify causes of impairment.

4. **Program Evaluation.** Monitor effectiveness of pollution abatement programs, including wastewater treatment, watershed restoration, and other water resource quality improvement programs. Biosurveys and the biocriteria benchmarks are used to assess the recovery of the aquatic community.

Purpose:
To provide guidance to technical staff for developing cost-effective biosurvey methods with appropriate resources, expertise, and technical considerations.

Detailed multidisciplinary ecological studies are often designed to examine aquatic systems by measuring the elements and processes of biological communities and by describing the physical and chemical characteristics of the waterbody. Biological attributes that may be included in such studies are individual health, trophic organization, measures of primary, secondary, and tertiary production (bodily growth and reproduction), recruitment of key species, predator-prey relationships, population dynamics, and taxonomic structure of assemblages.

While seasonal accommodation is preferable for most bioassessment programs, a single annual sample at a carefully selected time is sufficient

Quality assurance and control should be a continuous process throughout the development and operation of the biocriteria program, including all aspects of the study.

to characterize biological conditions accurately. Selection of the sampling period should be based on efforts to minimize variability and maximize the efficiency of the equipment and the accessibility of the biota being sampled. Minimal between-year variability is partially addressed by sampling at the same time each year to correct for the natural variability in seasonal cycles.

Water quantity, quality, and climatic conditions should help rather than hinder the efficiency of the sampling gear. For example, if certain flow conditions are necessary for the equipment's performance, sampling schedules should coincide with those conditions. Above all, sampling should occur when the targeted assemblage or assemblages are accessible. For fish, the optimal sampling period in most parts of the country is likely to be from June through September; in general, these months avoid high and low flows, spawning periods, and migration activity. Sampling should be timed to avoid extremes in environmental and biological conditions.

Quality Assurance Planning

A major consideration when designing bioassessment studies is not whether a particular biosurvey approach is more refined than another, but whether the selected approach will achieve the objectives defined in the management plan. A clear definition of management responsibilities and effective quality assurance and quality control procedures (see Chapter 2) are essential to ensure the usefulness of monitoring data (Plafkin et al. 1989).

Quality assurance plans have two primary functions (Klemm et al. 1990). The first function is to ensure that the survey process reliably meets program objectives; the second is to monitor the reliability of the survey data to determine their accuracy, precision, completeness, comparability, and representativeness.

Quality assurance and control pervade all aspects of an ecological study:

- *Study design*
- *Field operations*
- *Laboratory activities*
- *Data analysis*
- *Reporting*

A quality assurance plan should be developed at the onset of an ecological study to delineate responsibility, establish accountability, and ensure the reliability of the data (Stribling and Barbour, 1991). The quality assurance plan should answer three questions:

- What kind of data or information is needed?
- Why is the information or data needed?
- What level of quality is needed to ensure the reliability of decisions based on these data?

Quality assurance for a biocriteria program is concerned with the integrity of the data used to establish biocriteria limits and thresholds along with the documentation that supports the derivation and maintenance of the biocriteria. Quality assurance for specific studies pertains to the data acquisition, their application to established biocriteria, and the validity of associated judgments.

Quality assurance and control should be a continuous process throughout the development and operation of the program, including all aspects of the study: design, field collection, habitat assessment, laboratory processing of samples, database management, analysis, and reporting. The appropriateness of the investigator's methods and procedures and the quality of the data to be obtained must be assured before the results can be accepted and used in decision making. Quality assurance is accomplished through data quality objectives, investigator training, standardized data gathering and processing procedures, verification of data reproducibility, and instrument calibration and maintenance.

The use of data quality objectives in field studies (Klemm et al. 1990; Plafkin et al. 1989; U.S. Environ. Prot. Agency, 1984b, 1986) has much to offer the biocriteria development and implementation process. Data quality objectives are qualitative and quantitative statements within the quality assurance plan that address specific decisions or regulatory actions. Generally, data quality objectives consist of a priori statements about the level of uncertainty a decision maker will accept in environmental data. Once the objectives are stated, the quality of particular data can be measured using predetermined types and amounts of error associated with their collection and interpretation.

Quality Management

The implementation of a biocriteria program requires quality management or the proper combination of resources and expertise. State agencies will differ in levels of biological expertise, facilities, and quality of equipment. States already having well-developed bioassessment programs generally have experienced and well-trained biologists, appropriately equipped facilities, and properly maintained sampling gear. A successful biocriteria program depends on (1) a clear definition of goals, (2) the active use of biomonitoring data in decision making, and (3) the allocation of adequate resources to ensure a high quality program.

Biocriteria Program Structure, Personnel, and Resources

Monitoring agencies can and should enhance their program by cooperation with others. For example, they should seek coordination with, and staff assistance from, state fishery, land management, geology, agriculture, and water quality agencies. If federally employed aquatic biologists are stationed in a state or if the state has substantial federal lands, cooperative bioassessments and biocriteria development programs should be initiated. Scientists at state universities should also be included in the planning and monitoring phases of the program; their students make excellent field assistants and future state ecologists.

Monitoring agencies can and should enhance their program by coordination with, and staff assistance from, state fishery, land management, geology, agriculture, and water quality agencies.

■ **Personnel.** Several trained and experienced biologists should be available to provide more thorough evaluations, support for various activities, and serve as quality control checks. They should have training and experience commensurate with the needs of the program. At least one staff member should be familiar with establishing a quality assurance framework. The program should have at least one biologist for every 4,000 miles of stream in the state (C. Yoder and R. Thoma, personal communication).

■ **Resources.** Laboratory and field facilities and services should be in place and operationally consistent with the designed purposes of the program so that high quality environmental data may be generated and processed in an efficient and cost-effective manner (Klemm et al. 1990).

Adequate taxonomic references and scientific literature should support data processing and interpretation. The following program and technical considerations should guide the design and implementation of the biocriteria program.

■ Program Elements

1. Quality assurance and quality control (e.g., standard operating procedures, training)
2. Delineated reference conditions with annual updates corresponding to seasons of sampling
3. Multiple assemblage biosurvey
4. Habitat assessment
5. Documentation of program and study plans

■ Technical Considerations

1. Assign taxonomy to the lowest possible level based on published keys and descriptions; maintain voucher collections
2. Schedule multiple season sampling if warranted by type of impact and life strategy of assemblage
3. Use multiple metrics to refine the assessment
4. Initiate detailed quality assurance and quality control procedures in the field, laboratory, and taxonomy
5. Provide computer hardware and software (database management, data analysis) with computer training of staff

Different levels of training and experience are necessary for the personnel involved in biocriteria programs. The qualifications and general job descriptions of four levels of professional staff are presented here. Also described are suitable substitutions for these prerequisites and experience.

■ Professional Staff

1. **Level 4** — Plans, conducts, and supervises projects of major significance, necessitating advanced knowledge and the ability to originate and apply new and unique methods and procedures. Supplies technical advice and counsel to other professionals. Generally operates with wide latitude for unreviewed action.

   Typical Title: Project Manager, Chief Biologist.

   Normal Qualifications: Ph.D. or M.S. and equivalent experience.

   Experience: Ten or more years, at least three years in a leadership or managerial position.

2. **Level 3** — Under general supervision of project manager, plans, conducts and supervises bioassessment tasks such as trend monitoring or special studies. Estimates and schedules work to meet completion dates. Directs support assistance, reviews progress, and evaluates results; makes changes in methods, design, or equipment as necessary. Operates with some latitude for unreviewed action or decision.

Typical Title: Project Biologist, Group Leader, Crew Leader.

Normal Qualifications: M.S., B.S., or equivalent experience.

Experience: Six or more years in or related to bioassessment, two to three years in a supervisory capacity.

3. **Level 2** — Under supervision of a chief biologist or project manager, carries out assignments associated with projects. Translates technical guidance received from supervisor into usable data applicable to the particular assignment; coordinates the activities of juniors or technicians. Work assignments are varied and require some originality and ingenuity.

   Typical Title: Associate Biologist, Environmental Scientist.

   Normal Qualifications: B.S. or equivalent experience

   Experience: Three to eight years in or related to freshwater biology.

4. **Level 1** — Lowest or entering classification. Works under close supervision of a group or crew leader. Gathers and correlates basic data and performs routine analyses. Works on less complicated assignments that require little evaluation.

   Typical Title: Field Technician.

   Normal Qualifications: B.S. or Associate Degree and equivalent experience.

   Experience: zero to three years.

■ Experience/Qualifications Substitutions

1. Any combination of additional years of experience in the proposed field of expertise and full-time college-level study in the particular field totaling four years of structured, directed education may be substituted for a B.S.

2. A B.S. and any combination of additional years of experience and graduate-level study in the proposed field of expertise totaling two years may be substituted for the M.S.

3. A B.S. and any combination of additional years of experience and graduate study in the proposed field of expertise totaling four years; or an M.S. and two years of either additional experience or graduate-level study in the proposed field may be an acceptable substitute for the Ph.D.

4. Additional years of graduate-level study in an appropriate field will be considered equal to years of experience on a one-for-one basis.

The quality manager will identify project responsibilities and accountabilities for the bioassessment program. In states with limited resources, the basic responsibilities for all levels will rest with relatively few individuals; however, the accountability of each position will be quite distinct.

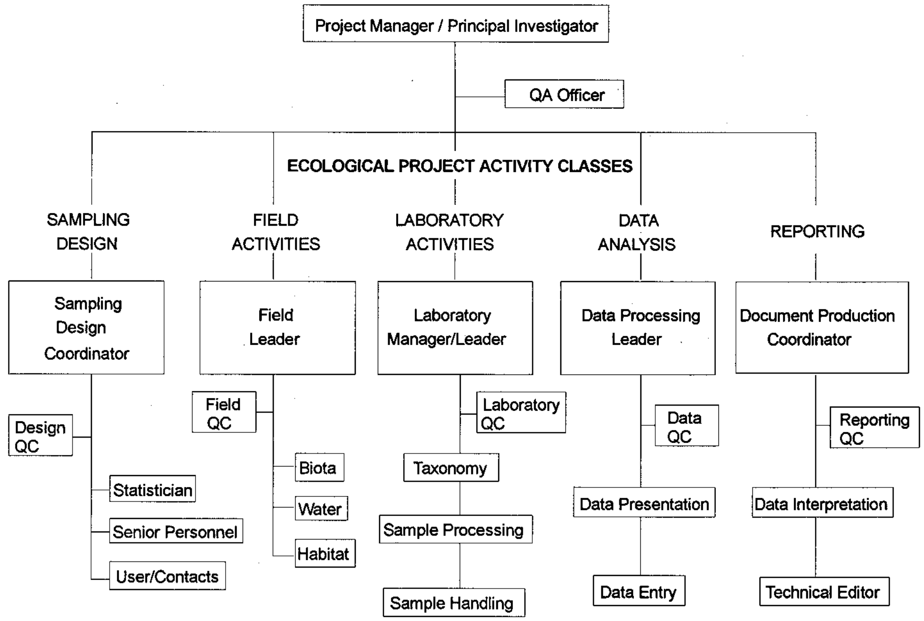

Figure 4-1.—Organizational chart illustrating project organization and lines of responsibility.

Quality management is an important planning aspect of the biocriteria development process that focuses attention on establishing and improving quality in all aspects of a project. Quality management requires that all personnel involved in a biocriteria project (from senior management to field and laboratory technicians) be aware of and responsive to data needs and expectations. The surest way to achieve total quality management (TQM) in an environmental program is to implement an achievable quality assurance program.

Effective quality control procedures are essential to insure the usefulness of the data for biocriteria development and environmental decision making, and to maintain the bioassessment program.

Quality Control Elements in an Ecological Study

Effective quality control procedures are essential to insure the usefulness of the data for biocriteria development and environmental decision making, and to maintain the bioassessment program. The organizational chart in Figure 4-1 identifies the major activity classes in an ecological project; Table 4-1 outlines the quality control elements that are integral to those activities.

All activity classes or phases of field ecological studies have potential error sources associated with them (Barbour and Thornley, 1990). Some general quality control elements for reducing error are discussed here; for more specific approaches, the investigator should refer to Klemm et al. (1990) for benthic macroinvertebrates; and to Karr et al. (1986), Lyons (1992), and Ohio Environ. Prot. Agency (1987) for fish.

■ **Study Design.** Considerations relating to potential error in the study design range from limited resources to insufficient sample replication to selection of inappropriate variables. Two important considerations for developing a study design are interrelated: the availability of baseline data in historical information or pilot studies and the capacity to identify poten-

Table 4-1.—Quality control elements integral to the activities in an ecological study.

A. Quality Management
   1. Delineate responsibilities
   2. List accountabilities
   3. Identify quality assurance officer
   4. Develop quality assurance plan
   5. Use bioassessment information in decision making

B. Study Design
   1. Pilot study or site reconnaissance
   2. Account for environmental strata
   3. Incorporate historical data
      a. Attempt to duplicate regimes
      b. Attempt to use similar equipment (if appropriate to current objectives)
   4. Termination of control point
   5. Areas of potential error
      a. Available resources
      b. Logistics
      c. Response variables
      d. Weather
      e. Seasonality
      f. Site selection
      g. Habitat variability
      h. Population variability
      i. Equipment
   6. Additional performance effect criteria

C. Sample Collection
   1. Instrument calibration and maintenance
   2. Field crew
      a. Training
      b. Evaluation
   3. Field equipment
   4. Sample handling
   5. Effort checks
   6. Field crew efficiency
   7. Areas of potential error
      a. Climate
      b. Site selection
      c. Sampling efficiency of equipment
      d. Equipment operation: human error
      e. Field notes
      f. Samples
         i. Processing
         ii. Transportation
         iii. Tracking
   8. Additional performance effect criteria

D. Sample Processing
   1. Sorting and verification
   2. Taxonomy
   3. Duplicate processing
   4. Archival procedures
   5. Training
   6. Data handling
   7. Interlaboratory training and collaboration
   8. Areas of potential concern
      a. Sample tracking
      b. Improper storage
      c. Sample preparation
      d. Reference error (taxonomy)
      e. Taxonomic error (human)

(continued on next page)

Two of the most important considerations in developing a study design are the availability of baseline data in historical information or pilot studies and the identification of potential sources of error.

Table 4-1.— Continued.

	f. Counting error
	g. Sorting efficiency
	9. Additional performance effect criteria
E.	Data Analysis
	1. Training
	2. Data
	a. Handling
	b. Reporting
	3. Standardized database
	4. Standardized analyses
	5. Peer Review
	6. Range control
	7. Statistical power analysis
	8. Areas of potential error
	a. Inappropriate statistics
	b. Errors in database
	c. Database management
	d. Programming errors
	e. Analytical misinterpretation
	9. Additional performance effect criteria
F.	Report Preparation
	1. Training
	2. Peer review
	3. Technical editor
	4. Standard format
	5. Areas of potential error
	a. Transcription
	b. Poor presentation
	c. Obscure language
	d. Addressing performance effect criteria
	6. Additional performance effect criteria

tial sources of error. In fact, having adequate baseline information may be the only way to identify sources of error. As more than one quality control element may be used to reduce potential error, the interaction among quality control elements must be considered to ensure the overall quality of the plan.

Six qualitative and quantitative characteristics are usually employed to describe data quality:

- **Precision.** The level of agreement among repeated measurements of the same characteristic.
- **Accuracy.** The level of agreement between the true and the measured value; the divergence between the two is referred to as bias.
- **Representativeness.** The degree to which the collected data accurately and precisely reflect the frequency distribution of a specific variable in the population.
- **Completeness.** The amount of data collected compared to the planned amount.
- **Comparability.** The degree to which data from one source can be compared to other sources.

- **Measurability.** The degree to which measured data remain within the detection limits of the analysis — often a function of the sensitivity of instrumentation.

These characteristics should be considered and defined before the data collection begins. Taken collectively, they provide a summary characterization of the data quality needed for a particular environmental decision.

■ **Field Operations.** The major quality control elements in field operations are instrument calibration and maintenance, crew training and evaluation, field equipment, sample handling, and additional effort checks. The potential errors in field operations range from personnel deficiencies to equipment problems. Training is the most important quality control element for field operations. Establishing and maintaining a voucher specimen collection is also important. Vouchers are a mechanism for achieving the source of the data, particularly for benthos. Use of a protocol for double data entry and comparison can also increase the quality of a database.

■ **Laboratory Operations.** The quality control elements in laboratory operations are classified as sorting and verification, taxonomy, duplicate processing, archival procedures, training, and data handling. Potential error sources associated with sample processing are best controlled by staff training. Controlling taxonomic error requires well-trained staff with expertise to verify identifications. Counting error and sorting efficiency are usually the most prominent error considerations; they may be controlled by duplicate processing, sorting, and verification procedures. Errors associated with transcription during the data entry process can be significant. In the laboratory, as in the field, the use of a protocol for double data entry and comparison can increase the quality of a database, and the establishment and maintenance of a voucher specimen collection should be considered.

■ **Data Analysis.** Peer review and range of values are the important quality control elements for data analysis. Peer review helps control operator variability, and measurement values must be kept within the range of natural or normal variability. Further, if inappropriate statistics are used to analyze the data, erroneous conclusions may be drawn regarding trends. Undetected errors in the database or programming can be disastrous, and unless steps are taken to oversee data handling and analysis, problems related to database management will arise. The use of standardized computer software for database management and analysis can minimize errors associated with tabulation and statistics. A final consideration is the possible misinterpretation of the findings. These potential errors are best controlled by qualified staff and adequate training.

■ **Reporting.** The quality control elements in the reporting activity include training, peer review, and the use of a technical editor and standard formats. The use of obscure language can often mislead the reader. Peer review and review by a technical editor are essential to the development of a scientific document. If the primary objective or central question of the study is not specifically addressed in the report or the report is ambivalent, then an error in the reporting process has occurred.

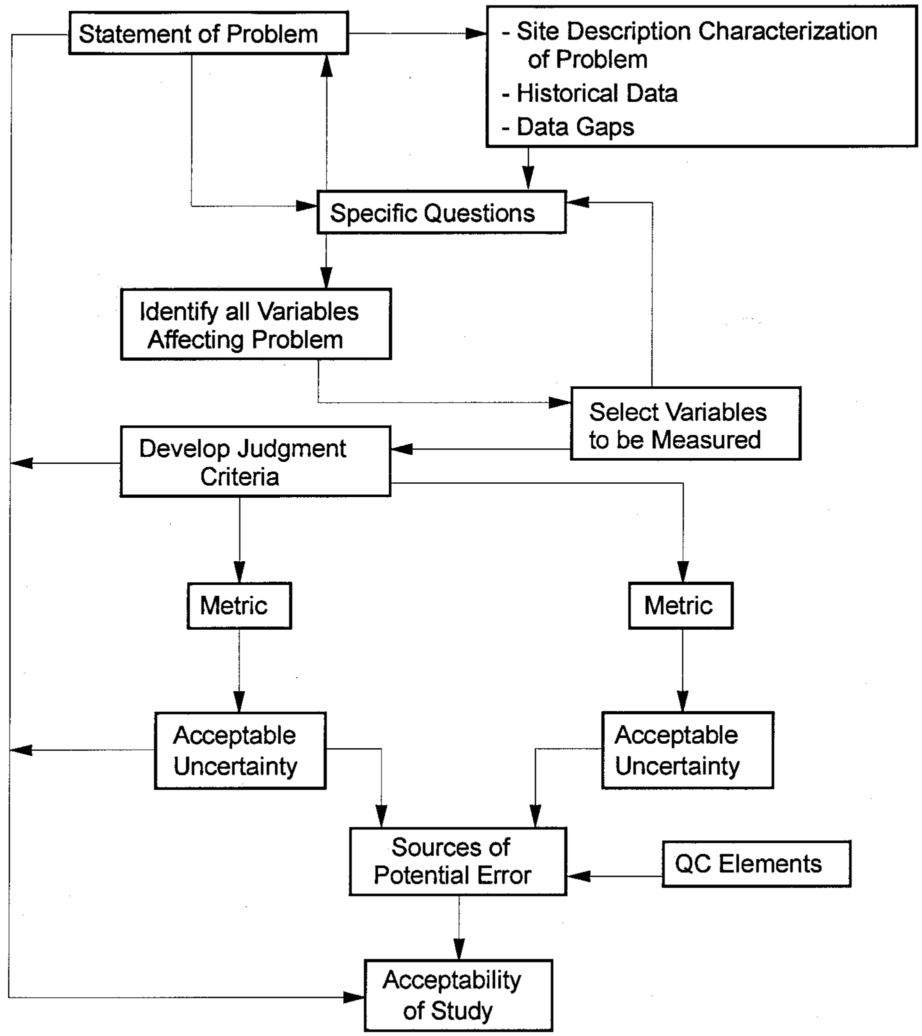

Figure 4-2.—Summary of Data Quality Objective (DQO) process for ecological studies (taken from Barbour and Thornley, 1990).

Data Quality Objectives

The data quality objectives process occurs during the final creation of the research design. Although its aspects are inherently interrelated, the development of data quality objectives is not directly linear. Rather, this development is an iterative or circular process, as shown in Figure 4-2. The initial statement of the problem evolves from specific questions about existing data; then comes the identification and selection of the variables to be measured, which influence the further refinement of the questions; and, finally, judgment criteria are developed for each variable, acceptable uncertainty levels are established, and sources of potential error are identified.

The result of the data quality objectives process is a formal document that can be separate from or part of a formal quality assurance plan. It may also be included in narrative form in a project workplan. The data quality objectives document should state the study's primary objectives, specific questions, and rationale; it should also justify the selection of variables, establish judgment criteria (by developing a logic statement for each variable), and specify acceptable levels of uncertainty. This information does not have to be presented in a stepwise fashion, but it should be readily available.

All staff involved in the biocriteria development process — senior management, program staff, and all technical staff — should be included in formulating data quality objectives. In fact, quality management in ecological studies requires that all personnel involved in a project be aware of and responsive to detailed needs and expectations. If appropriately executed, data quality objectives will formalize and document all management decision points, the necessary data collection and analysis procedures, the data interpretation steps, and the potential consequences of making an incorrect decision.

Further details of quality assurance and control programs specific to fish and macroinvertebrate field surveys, and methods for determining biological condition, are provided in Klemm et al. (1990) and Plafkin et al. (1989). General guidance for developing comprehensive quality assurance and control plans are discussed in the Code of Federal Regulations (40 CFR Part 30), and U.S. Environ. Prot. Agency (1980a,b; 1984a,c). For information and guidance specific to data quality objectives, see Klemm et al. (1990), Plafkin et al. (1989), and U.S. Environ. Prot. Agency (1984b, 1986).

The primary focus of the study design is to establish objectives, and the statement of the problem to be resolved is the central theme of the objectives.

Study Design

The primary focus of the study design is to establish objectives, and the statement of the problem to be resolved is the central theme of the objectives. For instance, the central problem or question may be, "Is the biological integrity of a specified area of a particular watershed impaired by the operation of a wastewater facility?" This question has several features that, in turn, provide a foundation for more specific questions. The first feature is the concept of biological integrity, which implies that a measurable reference condition exists for the aquatic assemblages being studied. The second feature delineates the spatial area to be evaluated in the watershed; the third determines whether or not a problem is attributable to the operation of the facility. Still more specific questions, or testable hypotheses, related to the central problem may be constructed.

1. Is impairment of the biological condition detectable in the algae, fish, or macroinvertebrate assemblages?
2. Is degradation altering the energy base, water quality, flow regime, habitat structure, or other aspect of the environment?
3. Is there a history of problems in this area of the watershed?
4. What was the historical condition of the aquatic community?

Based on these questions, it is possible to select the biotic and abiotic variables to be measured. For each variable, an acceptable level of degradation should be identified before conducting the biosurvey. Thus, the study design includes selecting the aquatic assemblages, resolving the technical issues associated with their ecology and proper sampling, establishing standard operating procedures, and beginning the biosurvey program.